COAL FOR COKE PRODUCTION

BY ARNO C. FIELDNER

* * * * * * * * * * Information Circular 7559

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by

Arno C. Fieldner[2]

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1/ Presented at meeting of the American Coke and Coal Chemicals Institute at Skytop, Pa., Oct. 4, 1949.

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INTRODUCTION

Coal for coke production is fundamentally necessary for the manufacture of pig iron, and pig iron must be had for making steel - a vital element in our modern industrial economy.

In both World Wars, special effort by Government and industry was required to meet the emergency of greatly increased demands. In the first World War, lack of coke-oven capacity, rather than lack of coking coals, was the principal problem; but in the second World War both oven capacity and coking-coal mining capacity were pushed to the utmost.

Because of inadequate supply, it became necessary to allocate a part of the production of these coals from other fuel use to coke production. This was done by the Solid Fuels Administration.

These experiences raised a question, during and after the war, as to the nature and amount of the minable reserves of coking coal suitable for the manufacture of metallurgical coke; and to what extent the lower-rank and lower-grade coals could be utilized by improving preparation and by appropriately blending different coals.

Obviously, much investigation and research are required to find answers to these questions. Some work was done by Governmental and industrial agencies during the war, and, fortunately, more has been undertaken since the close of the war. It is the purpose of this paper to review briefly our fuel reserves, with special reference to coking coal, and to discuss the problems of utilizing progressively poorer coking coals as the reserves of high-quality coals approach depletion.

FUEL RESERVES OF THE UNITED STATES

The United States is very fortunate in being richly endowed with mineral fuel resources. On a tonnage basis, we have about 40 percent of the geologically estimated coal reserves of the world, 35 percent of the proved petroleum reserves, and more than 90 percent of the known world reserves of natural gas.

The United States is also by far the greatest producer of solid, liquid, and gaseous mineral fuels. In 1947 we produced 38 percent of the world production of coal, 60 percent of all petroleum, and most of the natural gas.

Our proportionate rate of producing coal is well within our proportion of the proved world reserves, but our annual rate of producing oil far exceeds our proportion of the proved world petroleum reserves (see fig. 1). Therefore, to satisfy our large and still increasing demand for liquid fuel we must discover more petroleum reserves, import petroleum, or make synthetic liquid fuels from natural gas, oil shale, or coal. Probably each of these procedures will be employed to some degree.

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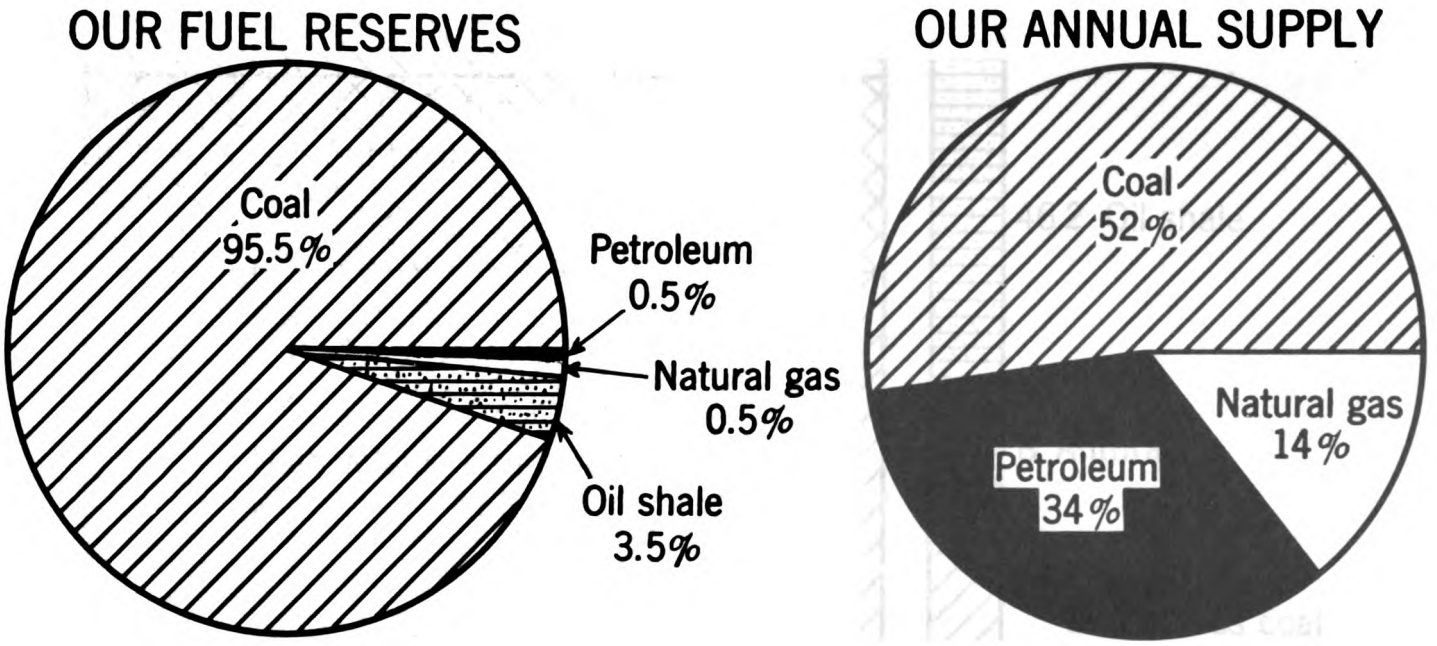

Figure 1. - Fuels for the future.

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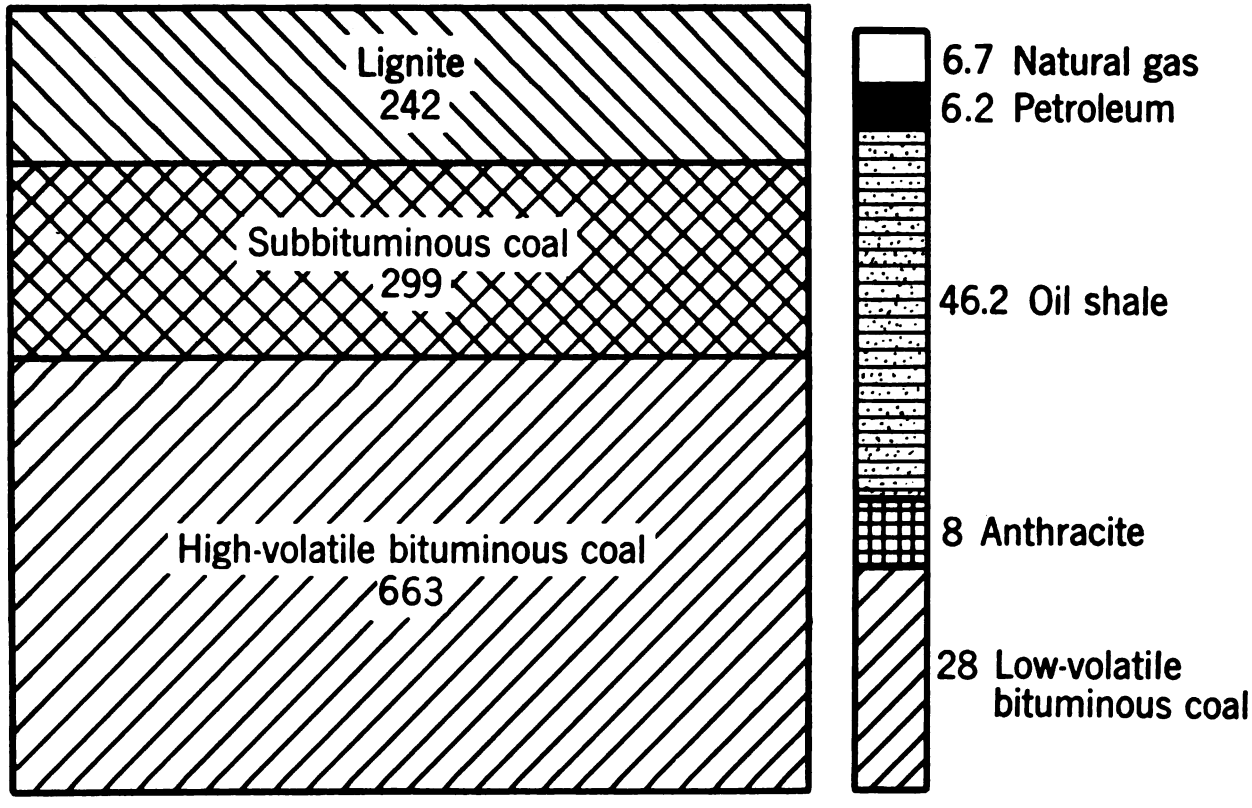

Figure 2. - Estimated fuel reserves of the United States, Jan. 1, 1949.

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Geophysical prospecting and exploratory drilling are proving additional domestic reserves of petroleum at an adequate rate to supply the increasing domestic demand, although the cost of discovery is constantly increasing. Increasing oil discoveries in South America, Canada, and the Middle East are making more oil available for importation and for supplying the growing demand of foreign countries. The first commercial plant for making oil from natural gas will go into operation early next year at Brownsville, Tex. The Bureau of Mines research at Rifle, Colo., has demonstrated that liquid fuel can be made from oil shale at a comparatively small increase in price over those prevailing in the last 2 years; and, finally, we have large reserves of coal and lignite that can be converted to liquid fuel as prices of petroleum rise still further.

Ultimately, coal will be the primary source, not only of solid fuels, but liquid and gaseous fuels as well, as we shall see from a comparison of the coal reserves with those of petroleum and shale and natural gas (see fig. 2).

The U. S. Geological Survey3/ estimated the total coal reserves of the United States, not including Alaska, at 3.1 trillion tons. This estimate includes beds down to 14 inches thick for anthracite and bituminous coal, 2 feet for subbituminous coal, and 3 feet for lignite and at depths not exceeding 3,000 feet. These are geologically inferred estimates and make no allowance for mining losses, nor do they consider that beds less than 2 feet thick are not economically minable at present.

As of January 1, 1949, committees of the American Petroleum Institute and of the American Gas Association estimated the proved reserves of crude oil at 23.3 billion barrels and natural-gas liquids at 3.5 billion barrels, a total of 26.8 billion barrels, and of natural gas at 174 trillion cubic feet.4/ The Bureau of Mines has estimated the oil recoverable from oil shale at about 200 billion barrels (see table 1).5/

Assuming that half of the coal reserves are recoverable, our mineral-fuel reserves have the following percentage distribution in terms of equivalent heating values:

	Percent
Inferred minable coal	95.5
Recoverable oil from oil shale	3.5
Proved petroleum and natural-gas liquids	.5
Proved natural gas	.5
	100.0

3/ Mineral Position of the United States, by the staffs of the Bureau of Mines and Geological Survey. Hearings before a Subcommittee of the Committee on Public Lands, U. S. Senate, 80th Cong., First Session, on Investigation of the Factors Affecting Minerals, Fuels Forestry, and Reclamation Projects, May 15, 16, and 20, 1947, p. 234.

4/ Oil and Gas Jour., vol. 47, No. 45, Mar. 10, 1949, pp. 44-45.

5/ Belser, Carl, Oil-Shale Resources of Colorado, Utah, and Wyoming: A.I.M.E. Pub. 2358, 1948.

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Whether we consider one-half or one-fourth of the coal reserves as minable, or whether two or four times as much oil and gas, as now proved, will be discovered, coal still will remain by far the largest source of mineral fuel.

However, it must be recognized that a very large proportion of the coal reserves is of low rank and of low grade, and that mining, to date, has been concentrated on the best and most easily mined coal.

TABLE 1. - Estimated recoverable mineral-fuel reserves of the United States[1/]

Description	Reserve, Jan. 1, 1948 or 1949	Assumed annual production	Equivalent billions of net tons bituminous coal, 13,000 B.t.u. per lb. calorific value[2/]			Reserve divided by assumed annual production
			Reserve, Jan. 1, 1948 or 1949	Percent of total fuel reserves	Assumed annual production	
1	2	3	4	5	6	7
Anthracite, billions of net tons.....	8	0.060	8	0.6	0.059	136
Low-volatile bituminous coal, billions of net tons[3/].....	26	.115	28	2.2	.124	226
High-volatile bituminous coal, billions of net tons[3/].....	639	.467	663	51.1	.485	1,367
Subbituminous coal, billions of net tons....	409	.014	299	23.0	.010	-
Lignite, billions of net tons.....	470	.004	242	18.6	.002	-
Total, all ranks of coal, billions of net tons.....	1,552	.660	1,240	95.5	.680	1,824
Petroleum, billions of barrels[4/5/].....	26.8	2	6.2	.5	.462	13
Oil from oil shale, billions of barrels.....	200	2	46.2	3.5	[6/].462	100
Natural gas, trillions of cubic feet[4/].....	174	6	6.7	.5	.231	29
Total, all fuels...			1,299		1.373	7/946

See footnotes on page 5.

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Footnotes for Table 1.

1/ Minable coal reserves are taken as half of the coal reserves estimated by the Geological Survey and given in mineral position of United States in hearings in 1947 before the Committee on Public Lands, U. S. Senate, and corrected for production to Jan. 1, 1948. Minimum thickness of beds included in the Geological Survey estimate is 14 inches for bituminous and anthracitic coals, 2 feet for subbituminous coal, and 3 feet for lignite. Beds are included to a depth of 3,000 feet below the surface.

2/ Heating values used in conversion: Anthracite, 12,700 B.t.u. per lb.; low-volatile bituminous coal, 14,000 B.t.u. per lb.; high-volatile bituminous coal, 13,500 B.t.u. per lb.; subbituminous coal, 9,500 B.t.u. per lb.; lignite, 6,700 B.t.u. per lb.; crude petroleum, 6,000,000 B.t.u. per bbl.; natural gas, 1,000 B.t.u. per cu. ft.

3/ Includes some medium-volatile coal.

4/ Proved reserves as of December 31, 1948.

5/ Includes 3.5 billion barrels natural gas liquids.

6/ Not included in the total of column 6.

7/ 946 is the reserve production ratio with no allowance for the approximately 50 percent thermal losses in conversion of coal to liquid and high-B.t.u. gaseous fuels. The following calculations allow for such losses on the assumption that after present proved petroleum and natural-gas reserves are exhausted, the assumed annual production of those fluid fuels will be made from coal. Assuming that half a ton of 13,000-B.t.u. coal is required to produce 1 barrel of oil and that 1/15 ton (recent calculations indicate 1/12 ton of coal may be required) of 13,000-B.t.u. coal is required to produce 1,000 cubic feet of 1,000-B.t.u. gas, to supply a current annual production of 2 billion barrels of crude petroleum and 6 trillion cubic feet of natural gas will require the conversion, respectively of 1,000 and 400 million tons, or a total of 1,400 million tons, of 13,000-B.t.u. bituminous coal.

This amount, added to 680 million tons of coal produced per year, would raise the total production of equivalent 13,000-B.t.u. coal required per year to produce all of the current consumption of gaseous, liquid, and solid fuels from 680 to 2,080 million tons per year - a little more than three times the present production.

In terms of 13,000-B.t.u. coal equivalent, the sum of the petroleum, oil-shale, and natural-gas reserves (6.2 + 46.2 + 6.7 = 59.1) divided by the sum of the annual production of petroleum and natural gas (0.462 + 0.231 = 0.693) equals 85 years, the life of these reserves.

In these 85 years, the total coal production at the assumed annual rate of 0.680 billion tons of equivalent 13,000-B.t.u. coal would be 85 x 0.680 = 57.8 billion tons, thus reducing the coal reserves to 1,240 - 58 = 1,182 billion tons.

1,182 ÷ 2.080 = 568, the years of life of coal reserves as exclusive source of coal, oil, and gas after proved petroleum oil-shale and natural-gas reserves are exhausted.

568 + 85 = 653 years, total life expectancy of all fuel reserves at 1948 rate of production of coal, oil, and natural gas, the oil and gas to be made from coal, following exhaustion of present proved reserves.

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RANK AND DISTRIBUTION OF COAL RESERVES

Tables 2 and 3 and figure 3 show the distribution, by rank and geographical location, of the inferred coal reserves on a heating-value basis. About 40 percent of the total reserves of coal and lignite occurs in the Eastern and Interior Provinces and 60 percent in the Northern Great Plains, Rocky Mountain, Gulf, and Pacific Coast Provinces.

TABLE 2. - Coal reserves on a B.t.u. basis distributed by ranks and provinces

Province	Billions of net tons of equivalent 13,000 B.t.u. coal				
	Anthracitic	Bituminous	Subbituminous	Lignitic	Total
Eastern.....	15.0	504.5	-	-	519.5
Interior.....	.2	491.0	-	0.1	491.3
Northern Great Plains, Rocky Mountain, Gulf, and Pacific Coast.....	.1	387.8	597.9	484.2	1,470.0
Total.....	15.3	1,383.3	597.9	484.3	2,480.8

TABLE 3. - Coal reserves on a B.t.u. basis percentage distribution by ranks and provinces

Province	Anthracitic	Bituminous	Subbituminous	Lignitic	Total
Eastern.....	0.6	20.3	-	-	20.9
Interior.....	-	19.8	-	-	19.8
Northern Great Plains, Rocky Mountain, Gulf, and Pacific Coast.....	-	15.7	24.1	19.5	59.3
Total.....	0.6	55.8	24.1	19.5	100.0

There is a great difference in rank between eastern and western coals. Virtually all of the Eastern and Interior Province coals, except anthracitic coals, are caking bituminous coals. The Appalachian region coals are medium to strongly coking and in 1947 supplied 95 percent of the coal used for making coke.

On the other hand, 75 percent of the coals of the Northern Great Plains, Rocky Mountain, Gulf, and Pacific Coast Provinces are subbituminous and lignitic. These coals do not cake on heating. As mined, lignite usually contains 28 percent to 45 percent moisture and subbituminous coal 15 percent to 28 percent moisture. On exposure to air, the moisture is given off and the coal slacks to small pieces. It is not stable and cannot be stored for any length of time except under water or in closed bins or in carefully covered piles where rapid loss of moisture cannot take place.

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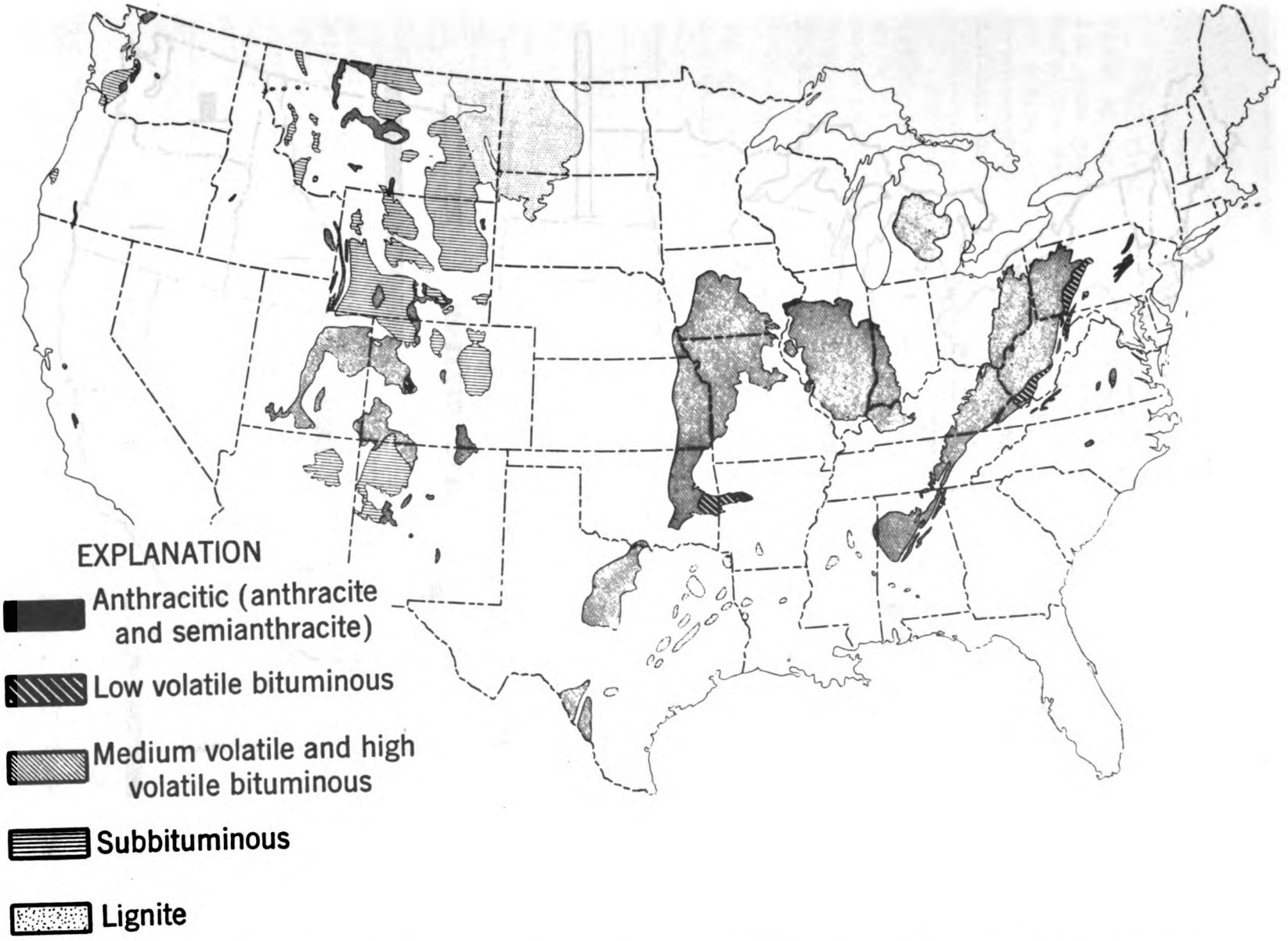

Figure 3. - Coal fields of the United States. (Prepared by the U. S. Geological Survey.)

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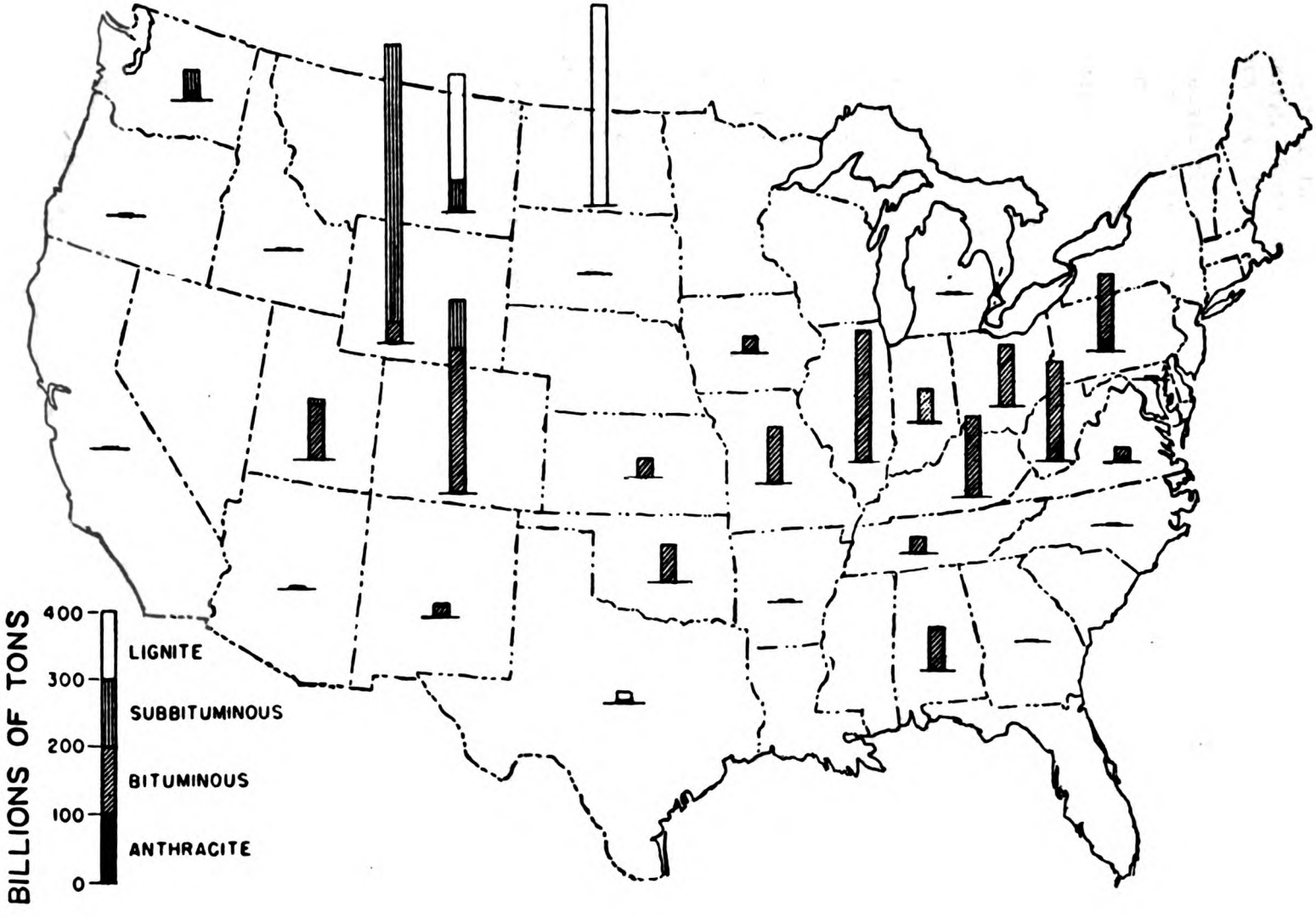

Figure 4. - Coal reserves, by States, as of Jan. 1, 1948. (Anthracite, subbituminous, and lignite reduced to bituminous coal equivalent.)

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Northern Great Plains, Rocky Mountain, Gulf, and Pacific Coast Provinces

Most of the bituminous coal in the Western States is free-burning and noncaking. Some of it is slightly caking but does not become plastic enough to form coke that is strong enough for blast-furnace use.

Relatively small reserves of good coking coal occur in the Trinidad-Raton field of southern Colorado and northern New Mexico. This coal has been used for some years by the Colorado Fuel & Iron Co. at Pueblo, Colo., for making metallurgical coke. Bureau of Mines engineers estimate the inferred reserves of coking coal in beds 3 feet and more thick as 850 million tons for the Trinidad field and 600 million tons for the Raton field. These estimates are made on the basis of U. S. Geological Survey and other data.

Another coking-coal reserve of probably greater extent but of poorer coking properties occurs in the Book Cliffs field of eastern Utah and western Colorado. The Sunnyside beds in Utah are supplying the coke ovens at Provo and Geneva, Utah, and Fontana, Calif. This coal has a high oxygen content and approaches the limit of suitability for making metallurgical coke with adequate physical properties for blast-furnace use.

A Bureau of Mines core-drilling program during and immediately after the war developed measured reserves of 15 million tons in southwestern Wyoming[6/] and 65 million tons of measured reserves in Gunnison County, Colo.[7/] These also are high-oxygen coking coals and are similar to the Sunnyside coal of Utah.

Some strongly coking, low-sulfur coals occur in Pierce and Kittitas Counties, Wash., but, unfortunately, they are high in ash and are difficult to mine owing to the pitching and faulting of the beds. Although some coke has been made from these coals in past years, none is being made at present. The recoverable reserves in Pierce County have been estimated at 60 to 120 million tons.

The Northern Great Plains, Rocky Mountain, Gulf, and Pacific Coast provinces contain approximately 60 percent of the Nation's coal reserves on an energy basis. This consists of 25 percent subbituminous coal, 20 percent lignite, and 15 percent bituminous coal. Only a small portion of the bituminous coal is coking. As shown in figure 4 and table 4, the lignite is principally in North Dakota and eastern Montana, the subbituminous coal in Wyoming, Colorado, and Washington, and the bituminous coal in Colorado, Utah, Wyoming, and Washington.

6/ Toenges, A. L., Davis, J. D., Turnbull, L. A., and Schopf, J. M., Reserves, Bed Characteristics, and Coking Properties of the Willow Creek Coal Bed, Kemmerer District, Lincoln County, Wyo.: Bureau of Mines Tech. Paper 673, 1945, 48 pp.

7/ Toenges, A. L., Turnbull, L. A., Davis, J. D., and Reynolds, D. A., Investigation of Coal Deposits in the Coal Creek District, Gunnison County, Colo. Progress Report 1: Bureau of Mines Rept. of Investigations 4104, 1947, 19 pp.

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TABLE 4. - Estimate of total coal reserves of United States, January 1, 1944, in billions of net tons[1/]

Order of reserves	State	Anthracite	Bituminous coal	Subbituminous coal	Lignite	Equivalent bituminous coal
	Alabama.....	-	66.5	-	-	69.1
	Idaho and Oregon	-	.7	1.8	-	2.0
	Arkansas.....	0.2	1.3	-	0.1	1.6
3	Colorado.....	.1	212.6	104.0	-	296.4
	Georgia.....	-	.9	-	-	.9
5	Illinois.....	-	197.2	-	-	204.7
	Indiana.....	-	51.8	-	-	53.8
	Iowa.....	-	28.7	-	-	29.8
	Kansas.....	-	29.6	-	-	30.7
6	Kentucky.....	-	121.0	-	-	125.2
	Maryland.....	-	7.7	-	-	8.0
	Michigan.....	-	1.9	-	-	2.0
9	Missouri.....	-	83.6	-	-	86.8
4	Montana[2/].....	-	2.6	62.8	315.5	211.1
	New Mexico.....	-	18.8	1.9	-	20.9
	North Carolina..	-	.1	-	-	.1
2	North Dakota....	-	-	-	600.0	309.2
8	Ohio.....	-	91.7	-	-	95.2
	Oklahoma.....	-	54.7	-	-	56.8
10	Pennsylvania....	14.9	65.0	-	-	82.0
	South Dakota....	-	-	-	1.0	.5
	Tennessee.....	-	25.2	-	-	26.1
	Texas.....	-	8.0	-	22.9	19.9
	Utah.....	-	87.9	5.1	-	95.1
	Virginia.....	.5	20.5	-	-	21.8
	Washington.....	-	11.2	52.4	-	49.9
7	West Virginia...	-	110.5	-	-	118.0
1	Wyoming.....	-	30.3	590.0	-	426.6
	Total.....	15.7	1330.0	818.0	939.5	2480.1

Total, all ranks of coal = 3,103 billion net tons.

1/ Investigation of Natural Resources: Hearings before a Subcommittee of the Committee on Public Lands, U. S. Senate, 80th Congress, May 15, 16, and 20, 1947, pp. 232-234.

2/ Combo, John X., Brown, Donald M., Pulver, Helen F, and Taylor, Dorothy A., Coal Resources of Montana: U. S. Geol. Survey Circular 53, August 1949. Gives the following reappraisal figures: Bituminous coal, 2,362,610,000 tons; subbituminous coal, 132,151,060,000 tons; lignite, 87,533,270,000 tons.

It is interesting to note that on a heating value basis Wyoming has the largest reserves, consisting of 590 billion tons of subbituminous coal and 30 billion tons of bituminous coal; North Dakota is second, with 600 billion tons of lignite; Colorado is third, with 213 billion tons of bituminous coal and 104 billion tons of subbituminous coal; and Montana is fourth, with 316 billion tons of lignite, 63 billion tons of subbituminous coal, and 3 billion

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tons of bituminous coal. These four States contain 51 percent of the Nation's coal and lignite energy reserves.

Alaska Coals

Two fields of coking bituminous coal are known in Alaska. These are near the coast and are designated the Matanuska field and the Bering River field. Several small mines have been developed in the Matanuska field, which supplied the Alaska Railroad before it changed over to oil. The Matanuska coal is not desirable for metallurgical coke as, even after washing, it contains 12 to 16 percent ash. The irregularity of the coal beds makes it very costly to mine.

The Bering River coal has never been developed, partly because of lack of harbor facilities near this region but also because of apparent irregularity, folding, and faulting of the beds. Local metamorphism has changed some of the coal to low-volatile bituminous and to anthracitic coal. The low-volatile coking coal would be especially desirable for western steel plants if it could be proved to occur in sufficient amount to justify development.

Interior Province Coals

The Interior Province includes Iowa, Missouri, Kansas, Oklahoma, and Arkansas in the western region and Illinois, Indiana, and western Kentucky in the eastern region.

Except for some anthracitic coal in Arkansas, almost all of the coal in the western region of the Interior Province is bituminous and cakes to some degree. Good coking coals occur in Oklahoma and Arkansas, and these supply steel plants in Texas that were built during the war. Also, low-volatile bituminous coal has been shipped to the western steel plants in Utah and California for blending with Utah high-volatile bituminous coal to make stronger coke. The addition of about 15 percent of this low-volatile bituminous coal to the oven charge greatly improved the physical properties of the coke. The percentage of breeze was reduced materially.

The Kansas coals are high-volatile bituminous coking coals, but most of them are too high in sulfur and ash to be desirable blast-furnace coke, and the same is true to a greater degree of the Missouri and Iowa coals. In northern Missouri and in Iowa the moisture and oxygen in the coals also increase to the point where they greatly reduce their coking properties.

The eastern region of the Interior Province, although smaller in area, has much larger reserves of coal than the western region. Although all the coals coke to some degree, they have not, as yet, found much use for metallurgical purposes because of the generally high content of ash, sulfur, and oxygen.

However, there are some good coking coals in limited areas in southern Illinois and western Kentucky that are now being used or considered for blending with higher-quality Appalachian coals. Next to these good coking

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coals, there is available a large reserve of fair coking coals which undoubtedly will come into future use as Appalachian reserves decline. Research on blending and coking treatment of these coals has been and is being conducted by the Illinois Geological Survey8/ and the steel industry.9/

Considerable progress also has been made by industry in the installation of mechanical washing and cleaning plants. In 1946, 44 percent of the Illinois and 49 percent of the Indiana output was washed, as compared to 24 percent of the Pennsylvania and 22 percent of the West Virginia outputs in the Eastern Province, where the coal is lower in ash and sulfur content. These figures apply to all coal mined whether used for making coke or for other purposes. All coal mined in Colorado and used for the manufacture of coke was washed; most of Tennessee's and Alabama's and about one-third of Pennsylvania's was washed before being charged into ovens.

Eastern Province Coals

The Appalachian region supplied 95 percent of the coal coked in 1947. Pennsylvania and West Virginia each supplied 35 percent, Kentucky, 14 percent, Alabama, 9 percent, Virginia, 2 percent, Utah, 2 percent, and Colorado 1 percent.

West Virginia has the greatest reserves of the best grades and highest rank of bituminous coals of any State in the union. These excellent coking coals extend into Virginia and eastern Kentucky. Pennsylvania is second to Virginia in reserves of high-, medium-, and low-volatile bituminous coking coals.

The geologically estimated coal reserves of Alabama are of about the same order as those of Pennsylvania, and they have supported the Alabama steel industry for a number of years. However, these coals required washing to remove ash-forming material. The best coking coals are in the Warrior field, near Birmingham. The northwestern part of this field contains coals of higher volatile matter and weaker coking properties. Also, the coals in the other fields are of lower coking quality. Blending studies of these various coals should be undertaken to extend the life of the best coking coals by blending them with the inferior coals as far as possible.

Reserves in beds of minable thickness10/. - The geologically inferred bituminous-coal reserve of the entire Eastern Province is estimated at approximately 500 billion tons. This figure appears very large and sufficient to

8/ Reed, F. H., Jackman, H. W., Rees, O. W., Yohe, G. R., and Henline, P. W., Use of Illinois Coal for Production of Metallurgical Coke: Illinois State Geol. Surv. Bull. 71, 1947, 132 pp.

9/ Isenberg, N., and Jackman, Harold W., Investigation of Beckley Seam Coal Blended with Wheelwright Coal for Use in the Production of Metallurgical Coke Under the Supervision of E. J. Gardner, Supt. of Blast Furnaces and Coke Plant, Inland Steel Co., East Chicago, Ind.: 1945, 200 pp.

10/ For an excellent discussion of the quality and estimated quantity of coking-coal reserves, see article by F. M. Becker, Reserves and Future of Coking Coals in the United States: Proc., Blast-Furnace, Coke-Oven, and Raw-Materials Committee of the Iron and Steel Division, A.I.M.E., 1947, pp. 3-22.

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last for thousands of years. However, closer examination greatly reduces this estimate, based on recoverable reserves under present-day mining practice and standards of quality. The geologically inferred reserve estimates include beds down to 14 inches thick, depths as low as 3,000 feet, and ash contents up to 30 percent. Only 1.2 percent of the coal and lignite mined in the United States in 1945 was obtained from beds less than 2 feet thick;11/ 5.7 percent of the production was obtained from beds 2 to 3 feet thick; 47.6 percent from beds 3 to 5 feet thick; 27.5 percent from beds 5 to 7 feet thick; and 18 percent from beds 7 feet thick and over. Thus, we see that only 7 percent of the coal mined in 1945 came from beds less than 3 feet thick. In 1920, 6 percent of the production came from beds less than 3 feet thick. No material improvement has taken place in the recovery of coal from thin seams over a period of 20 years, and, unfortunately, a very large part of the estimated coal reserves occurs in beds less than 3 feet thick.

Ashley estimated that 45 percent of the remaining bituminous-coal reserves of Pennsylvania consists of beds between 1 and 2 feet thick and that 55 percent is included in beds above 2 feet in thickness.12/

In view of this estimate, it seems reasonable to assume that at least 50 percent of the 500 billion tons of geologically inferred bituminous-coal reserves of the Eastern Province is coal thicker than 2 feet. This would be 250 billion tons. However, all of this coal will not be recovered.

Recoverable reserves. - A field investigation, covering 10 States, of losses in mining bituminous coal was made by the United States Coal Commission and the Bureau of Mines in 1923.13/ In this study, the losses were classified as "unavoidable" or as "avoidable without undue danger to life, without undue labor per ton of product much in excess of that now prevailing in the bituminous mines of the country, and without serious damage to buildings and engineering works on the surface." The unavoidable losses were found to average 15.3 percent of the coal in the mines then operating, and the avoidable losses were 19.4 percent. The total loss was 35 percent and the average recovery 65 percent.

These losses referred only to current operations of active mines and consisted of:

11/ Young, W. H., and Anderson, R. L., Thickness of Bituminous Coal and Lignite Seams Mined in the United States in 1945: Bureau of Mines Inf. Circ. 7442, 1948, 17 pp.

12/ Ashley, Geo. H., Chapter on Coal in "Pennsylvania's Mineral Heritage:" Pennsylvania Department of Internal Affairs, Bureau of Statistics, Topographic and Geologic Survey, Harrisburg, Pa., 1944, P. 83.

13/ Rice, George S., and Paul, J. W., Amount and Nature of Losses in Mining Bituminous Coal in Eastern United States: In Report of U. S. Coal Commission, pt. III, 1925, pp. 1841-1876.

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1. Coal left on the roof and bottom.
2. Coal lost in room, entry, and panel pillars.
3. Coal lost in pillars around oil and gas wells.
4. Coal lost under buildings, railroads, and in boundary pillars.
5. Coal lost in handling and preparation, underground and surface.
6. Coal lost in rolls, thin or dirty areas.

Rice, Fieldner, and Tryon[14] in 1936 called attention to additional losses and irrecoverable coal, such as patches of uneconomically minable coal left behind when a mine is abandoned, areas so small in extent or so isolated that even for the future they give no promise of being mined economically, and fracturing of overlying beds by prior mining of better or thicker seams lying a short distance below. They considered the total amount of such waste as indeterminate but undoubtedly large.

It is not known whether the greatly increased mechanization of coal mines since 1923 has increased or decreased mining losses. It is believed that the average recovery is no greater than it was 25 years ago and that the additional losses, not included in the Coal Commission's report, indicate an average recovery of 50 percent of the minable coal, which would make the recoverable coal in beds over 2 feet thick about 25 percent of the 500 billion tons of geologically inferred reserves, or 125 billion tons.

This is subject to further reduction, because it includes coals with ash content up to 30 percent and no limit as to sulfur content and some poorly coking coals. Information is not available for estimating the proportion of low-grade coking coals.

Reserves of low-volatile bituminous coal. - An especially important part of our coking coal resources is the low-volatile bituminous coals. These are inherently the most valuable of all ranks of coal because of their high heating value, their semismokeless properties, and their special coking value. Admixture of 15 to 30 percent of these coals in the coke-oven charge permits the use of high-volatile coals that by themselves produce coke of inferior physical properties.

Classification of all coal received for coking in slot-type ovens in 1947 showed that 65 percent was high-volatile, 14 percent medium-volatile, and 21 percent low-volatile. Of 86 active coke-oven plants, 46 carbonized blends of high- and low-volatile coals, 25 carbonized blends of high-, medium-, and low-volatile coals, 3 carbonized blends of medium- and low-volatile coals, and 2 plants carbonized blends of high- and medium-volatile coals.[15]

With the low-volatile coals comprising 21 percent of the coal used for coke production and only 4 percent of the bituminous coal reserves, it is obvious that coal of this rank will be exhausted long before the high-volatile coking coals are consumed. Therefore, let us examine more closely the status of the reserves of low-volatile coal.

14/ Rice, George S., Fieldner, A. C., and Tryon, F. G., Conservation of Coal Resources: Trans., Third World Power Conference, Washington, D. C., 1936, vol. 6, pp. 690-691.

15/ Preprint from Bureau of Mines Minerals Yearbook, 1947: Coal-Anthracite, Cobalt, Coke, and Coal Chemicals, p. 413.

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According to the U. S. Geological Survey, the original reserve of semi-bituminous, now called low-volatile bituminous coal, had the following distribution:

	Millions of net tons
Pennsylvania	9,574
Maryland	6,536
West Virginia	29,800
Virginia	400
Arkansas	1,226
Oklahoma	8,000
Other States	834
Total	56,370

Dividing this amount by 2 to allow for beds less than 2 feet thick, and again by 2 to allow for mining losses, give 14 billion tons, in round numbers, of low-volatile bituminous coal of all grades (i.e., less than 30 percent ash). This amount is 166 times the 84 million tons of low-volatile coal mined in 1947. However, this does not mean that we have a usable supply to last the country for this period of time. As shown in table 5, the consumption of low-volatile coal for coke production virtually doubled in the 20 years that elapsed between 1927 and 1947. Also, its use for other purposes increased in greater proportion. Increasing use will continue and greatly shorten the life of the reserves. In addition, the original inferred estimates may be too large, and no one knows the proportion of coal that is too high in ash or sulfur to be usable for making metallurgical coke.

TABLE 5. - Origin of coal received for coke production at slot-type ovens in the United States, 1927 and 1947

Source	Thousands of net tons		Percent of total	
	1927	1947	1927	1947
Low-volatile:				
Arkansas	-	123	-	0.1
Maryland	1	42	1/	1/
Oklahoma	-	52	-	0.1
Pennsylvania	2,025	3,783	3.1	3.9
Virginia	54	1,091	.1	1.1
West Virginia	9,648	15,482	15.0	15.9
	11,728	20,573	18.2	21.1
Medium-volatile:				
Alabama	6,308	8,064	9.7	8.3
Arkansas	-	57	-	.1
Georgia	46	-	0.1	-
Kentucky	730	174	1.1	0.2
Pennsylvania	3,268	761	5.1	.8
Tennessee	108	136	.2	.1
Virginia	27	484	1/	.5
West Virginia	3,649	3,740	5.7	3.8
	14,136	13,416	21.9	13.8

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TABLE 5. - Origin of coal received for coke production at slot-type ovens in the United States, 1927 and 1947 (Cont'd.)

Source	Thousands of net tons		Percent of total	
	1927	1947	1927	1947
High-volatile:				
Alabama	266	421	0.4	0.4
Colorado	986	907	1.5	1.0
Illinois	437	505	.7	.5
Indiana	8	129	1/	.1
Kentucky	8,630	13,727	13.5	14.1
New Mexico	-	588	-	.6
Ohio	1	-	1/	-
Oklahoma	-	81	-	0.1
Pennsylvania	22,473	29,672	34.9	30.5
Tennessee	-	19	-	1/
Utah	324	2,122	0.5	2.2
Virginia	1,317	501	2.0	.5
Washington	65	-	.1	-
West Virginia	4,089	14,664	6.3	15.1
	38,596	63,336	59.9	65.1
Grand total	64,460	97,325	100.0	100.0
Total coal charged:				
Beehive	11,208	10,475		
Slot-oven	63,240	94,587		
Total	74,448	105,062		
Total coke produced	51,092	73,446		
Percent coke yield	68.63	69.91		

1/ Less than 0.05 percent.

Depletion of Best-Coking Coals

Thirteen years ago, Rice, Tryon, and Fieldner, in a paper on the conservation of coal resources presented at the Third World Power Conference in Washington, made the following statement:

> ***the finest seams are being used up much faster than is supposed. Some, indeed, are nearly exhausted already, such as the Blossburg coal of Pennsylvania, the Sharon bed in northern Ohio, and those portions of the Brazil block seam of Indiana that are suitable for underground mining. The famous Moshannon seam in the basin of that name in the Clearfield, Pennsylvania, district is virtually exhausted, and only a few acres of virgin coal remain in the celebrated Georges Creek Big Vein of Maryland.
>
> Still others of the finest beds are seriously depleted or have short expectation of life. The anthracite reserves of Pennsylvania are 29 percent exhausted. The low-sulfur coals of

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> southern Illinois have a distinctly limited life. The life of the famous Connellsville coking coal is placed at from 20 to 30 years at 1929 rates of production, and that of the Pittsburgh bed in the State of Pennsylvania at 100 years. At 1929 rates, also, the reserves of the "smokeless" coals of southern West Virginia in beds of present workable thickness and quality are sufficient to last but 85 years. Thinner beds in this area, as mapped by the State Geological Survey, contain enough coal for perhaps an additional 60 years. Even in the relatively more abundant high-volatile coal of the southern Appalachians, depletion of the beds of highest value is becoming a factor to be reckoned with. The highest-grade gas and metallurgical coals in beds now commercially workable are 11 percent exhausted in Kentucky and 22 percent exhausted in southern West Virginia and Virginia.16/

The heavy demand for steel, with the concomitant demand for coke of World War II, has made the situation with respect to good coking coals more serious than visualized in this paper. The low-volatile blending coals were in especial demand, and this is being increased by the adoption of more severe smoke-abatement ordinances in the larger cities. St. Louis, Mo., and Pittsburgh, Pa., have prohibited the use of high-volatile coal in furnaces unless they are equipped with mechanical stokers. This compels the use of smokeless fuels in furnaces not so equipped. Low-volatile bituminous coal is semismokeless, and its use is permitted. Considerable low-volatile smokeless coal is being used for this purpose (probably twice the amount used for making coke), thus further reducing the reserves available for the production of metallurgical coke.

According to Bureau of Mines distribution statistics, only about 25 percent of recent production of low-volatile coal is used in the manufacture of coke. About 50 percent is sold to the retail trade, and 25 percent is used for other industrial purposes.

Voskuil has called attention to this important aspect of the depletion of coking-coal reserves with respect to the quantity of coking coal mined and not used for the manufacture of metallurgical coke. He quotes a survey made by the Bureau of Mines of coking coal produced in 1940, which disclosed that counties producing coking coal shipped a total of 171 million tons of coal, of which 77 million tons was made into coke. This was only 45 percent of the total.

> An examination of coal production by counties in Pennsylvania, West Virginia, and Alabama covering the period 1916 to 1944 shows a substantial decline in output in such important coal counties as Alleghany, Fayette, and Westmoreland in Pennsylvania, offset by an increase in practically all counties producing coking coal in West Virginia. Meanwhile, output in Alabama remained relatively unchanged.17/

16/ Rice, George S., Fieldner, A. C., and Tryon, F. G., Conservation of Coal Resources: Trans., Third World Power Conference, Washington, D. C., 1936, vol. 6, pp. 679-680.

17/ Voskuil, Walter H., Coke - A Key Industrial Material: State Geological Survey, Urbana, Ill., Circular No. 127, p. 345.

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In other words, Pennsylvania has had its best days as a producer of coking coals. Depletion of the best grades of coal compels the utilization of lower grades, of which there still remains a moderate reserve.

The question has been raised as to whether or not coking coal should be conserved for coking purposes only and not used for heating where other coals can be used. Such a national policy would appear desirable from the standpoint of best utilization of our national fuel reserves. However, there are serious difficulties in adopting such a plan of allocating fuels for various uses in time of peace. The same suggestions have been made with respect to preventing the use of petroleum and natural gas for stationary industrial heating and power development where coal can be used, on the ground that the reserves of oil and gas are much smaller than those of coal and that they have special uses for which coal is much less suitable, as for automotive transportation, in case of liquid fuels, and convenient residential heating, in case of natural gas.

RESEARCH ON UTILIZING LOWER-GRADE AND LOWER-RANK COALS

Probably the most progressive plan is to continue our present policy of allowing free competition between the different forms of fuel and encouraging research to overcome the disadvantages of so-called inferior fuels. Such a plan is particularly applicable to making use of the lower ranks and lower grades of coking coal of which there are large reserves in the Eastern and Interior Provinces. These coals can be up-graded, more or less, by suitable methods of washing and by blending them with appropriate high-rank coals, thus extending the total reserves of usable coking coal. Industry already has recognized this need and is giving increasing attention to preparation and blending by supporting research and applying the results to operating practice.

Improvement in Coal Preparation

An outstanding example of utilizing lower-grade coal is the recent development of the 25,000-ton-a-day Robena mine of the H. C. Frick Coke Co., in the relatively high-sulfur area of the Pittsburgh coal bed in Greene County, Pa. The coal as mined varies from 1 to nearly 3 percent sulfur content and averages about 2 percent sulfur. Through installation of a dense-media "float and sink" process and appropriate crushing of the coal, it is hoped to reduce the original sulfur to about 1.7 percent and the ash to about 7 percent.

Lack of material during the war retarded the installation of coal-washing plants, and the percentage of metallurgical coal that was washed increased only from 28.2 percent in 1944 to 29.4 percent in 1948.

Since the war, the Bureau of Mines has undertaken some field and laboratory studies on the preparation of coking coal. This program is divided into two general divisions: (1) a survey of the washing characteristics of coals, by beds and mining fields, and (2) an experimental study of processes for separating the good from the poorly coking constituents of coals of marginal coking quality.

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Sample number	Organic sulfur	Pyritic sulfur		Total sulfur
		1.35 float	Removed	
24	0.72	0.15	0.22	1.09
7	.74	.14	.05	.93
4	.76	.12	.24	1.12
25	.75	.19	.21	1.15
6	.74	.25	.10	1.09
14	.85	.14	.21	1.20
18	.84	.22	.40	1.46
17	.91	.16	.45	1.52
23	.78	.30	.01	1.09
15	.91	.20	.55	1.66
13	.89	.30	.44	1.63
2	.84	.36	.15	1.35
12	.87	.33	.50	1.70
22	.75	.46	.37	1.58
16	.95	.28	.33	1.56
26	.76	.56	.16	1.48
3	.89	.51	.31	1.71
27	.80	.61	.16	1.57
1	.87	.57	.37	1.81
11	.94	.54	.95	2.43
19	.97	.52	.94	2.43
10	1.04	.49	.86	2.39
33	.93	.61	.39	1.93
35	.91	.64	.47	2.02
20	.94	.61	.55	2.10
5	.85	.72	.26	1.83
9	1.06	.53	.71	2.30
34	.94	.68	.41	2.03
8	1.01	.65	.55	2.21
21	1.07	.74	.34	2.15
36	.99	.89	.53	2.41
37	1.04	.91	.83	2.78
29	1.44	.70	.71	2.85
32	1.44	.74	.25	2.43
31	1.58	.65	.64	2.87
30	1.44	.83	.96	3.23
28	1.43	.91	1.03	3.37

Figure 5. - Variations in sulfur forms and content of 37 face samples of 1-1/4- by 3/8-inch coal from the Shanopin mine.

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A preparation survey of a typical high-sulfur area of the Pittsburgh coal bed in Greene County, Pa.,[18] showed how variations in the forms of sulfur occurring in the coal affected the practical problem of reducing the sulfur content. Face samples taken at 37 locations in one mine showed irregular variations in total sulfur content and in content of the various forms of sulfur. As illustrated in figure 5, the total sulfur ranged from a minimum of 0.9 to a maximum of 3.4 percent, the organic sulfur from 0.7 to 1.6 percent, the unremovable, finely divided, pyrite sulfur in the 1-1/4-inch by 3/8-inch float coal from 0.1 to 0.9 percent, and the removable sulfur from 0.1 to 1.1 percent. Almost half of the samples showed more than 1.5 percent of unremovable sulfur, and a number of them over 2 percent.

These conditions presented a difficult washing problem, for which the following not wholly satisfactory solutions were suggested:

1. Separate, in mining, the coals from the high- and low-sulfur areas. Wash the low-sulfur coal at the usual 1.60 specific gravity, obtaining a single metallurgical product of about 1.4 percent sulfur and 88 percent recovery. Wash the high-sulfur coal separately at the same gravity, recovering 90 percent of a steam coal containing about 8 percent ash and 3 percent sulfur.

2. Blend the high- and low-sulfur coals to obtain a uniform composition going to the preparation plant and wash it at about 1.35 specific gravity to obtain a metallurgical product; then rewash the refuse at a higher gravity, making a steam-coal product, or crush the refuse to about 100 mesh and clean by froth flotation to obtain a metallurgical product.

This study, made at the Shanopin mine in Greene County, is now being extended to other high-sulfur areas in southwestern Pennsylvania, northern West Virginia, and southern Illinois. Special attention is being given to the marginal coals, which do not yield a metallurgical coal of satisfactory sulfur content by the conventional coal-washing processes. It is possible that two-step high- and low-gravity washing, resulting in a metallurgical- and a steam-coal product, may eventually be developed for obtaining a worthwhile yield of metallurgical coal from the high-sulfur areas of the Eastern and Interior Provinces.

Further improvement of the recently developed dense-media "float-and-sink" washing processes probably will permit operation with coal of smaller sizes and thus obtain greater reduction of ash and sulfur than in the older processes. Research should be continued on an increasing scale on the further improvement of preparation techniques and the consideration of radically new methods for the reduction of ash and sulfur in coal.

Blending Coals for Coke Production

Research also should be greatly increased on blending our strongly coking coals with as much weakly coking coal as possible so as to utilize the large

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18/ Fraser, Thomas, and Crentz, W. L., Washing Characteristics of the Pittsburgh Coal in a High-Sulfur Area in Greene County, Pa.: Bureau of Mines Tech. Paper 689, 1946, 85 pp.

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reserves of low-rank coking coals found in parts of the Appalachian Region and in Indiana, western Kentucky, and Illinois. We must begin to use these low-rank coals long before the high-rank coals are exhausted, otherwise we will not have any high-rank coals to blend with them. In most cases, a better coke can be made by a judicious blend of two or three different coals than can be made from any one of the three by itself.

The blending of high- and low-volatile coal is common practice in order to obtain a strong coke, relatively free from shrinkage cracks, and a minimum of coke breeze. In the future, the problem of blending will be much greater owing to shortage of the most desirable coals. This need is being recognized by industry, and much more attention is being given to research with experimental small and full-scale ovens, primarily for the determination of the physical properties of cokes obtainable with various blends of coals. This includes research on the expanding properties of the coal charge and the effect of various size consists of the charge.

Some years before the beginning of World War II, the Bureau of Mines, in cooperation with the American Gas Association, started an experimental study of the properties of American coals for making gas, coke, and chemical products. A method using 100 to 200 pounds of coal heated in a cylindrical iron retort was developed. This procedure, known as the Bureau of Mines-American Gas Association (BM-AGA) method, was applied to a survey of American coals, and a number of publications of the Bureau have been issued that give the yields and quality of the products obtained at various carbonization temperatures ranging from low- to high-temperature practice. These data were of immediate value when it became necessary to select coking coals from the Oklahoma-Arkansas field for supplying the wartime blast furnaces and coke-oven plants installed in Texas.

The Bureau of Mines has installed experimental slot-type ovens of about 400 pounds coal capacity at the Golden, Colo., Tuscaloosa, Ala., and Pittsburgh, Pa., experiment stations for conducting blending experiments with special reference to the physical properties of the resulting coke. Ovens of this size and type have been found to give results approaching those obtained in commercial-scale ovens. At Tuscaloosa, studies are being started on blending the strongly coking coals of the southeastern portion of the Warrior field with the weaker coking coals of the western and northwestern parts of the field. Such blending will be necessary in the future as the reserves of the better coals become depleted.

The Golden, Colo., experimental oven is planned for similar work on western coking coals. At this station, also, some work is being undertaken on blending noncoking bituminous coals with good-coking coals.

As previously stated, the Illinois Geological Survey and the steel industry operating in Illinois and Indiana are actively interested in blending high-oxygen Illinois coal with the stronger-coking coals of eastern Kentucky and West Virginia to obtain a satisfactory metallurgical coke. Experiments on making a low-temperature carbonization product from Illinois coal as a substitute for low-volatile bituminous coal are now in progress at

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Urbana, Ill. Likewise, the Russell[19] expansion oven developed by the Koppers Co. has been installed at a number of coke-oven plants where its use has facilitated practical blending studies. As a result of developments in washing and blending methods, great progress will be made in the next decade in extending our coking-coal reserves to the lower ranks of coking coal.

SURVEY OF MINABLE RESERVES OF COKING COAL

One of the most important projects for the Government to carry out in the immediate future is a reappraisal of the national coal reserves in much greater detail than the previous one made many years ago by M. R. Campbell of the U. S. Geological Survey. He did most of his work before the first World War with comparatively little help and with considerably fewer data from exploratory drilling and operating mines than have become available in recent years. Most of his estimates were based on geological inferences, and experience has shown that they tend to be too large rather than too small.

Andrew B. Crichton,[20] of Johnstown, Pa., believes that the original Campbell estimates are much too large and has pointed out that an unknown but large portion of the coal included in these estimates is not economically minable by methods now known. He suggests that recoverable and usable coal may comprise as little as 10 percent of the geologically inferred deposits as now given.

Following presentation of this paper, the American Institute of Mining and Metallurgical Engineers appointed a committee of geologists and mining engineers, under the chairmanship of Henry F. Hebley, to investigate the possibility of instituting a new survey of the national coal reserves. About the same time, the National Bituminous Coal Advisory Council to the Department of the Interior set up a Coal Resources Committee, with the late Charles O'Neill as chairman, to consider the same problem and prepare recommendations to the Secretary of the Interior for carrying out the survey.

Joint meetings of both committees were held with representatives of the Geological Survey and the Bureau of Mines, who already were engaged in expanding their work along these lines as far as possible with existing appropriations. The Geological Survey work at that time was largely on western coals, and the Bureau of Mines had just started on a survey of the minable reserves of coking coal in the Appalachian region as determinable from examination of core-drilling and other data held by mining and land companies and other agencies.

A plan of carrying out these surveys was agreed upon at these meetings, and the Interior Department, through the Geological Survey and the Bureau of Mines, is well started on the new survey.

19/ Russell, C. C., Measurement of Pressure Developed During the Carbonization of Coal: A.I.M.E. Tech. Pub. 1118, 1939, 14 pp.; Trans., Coal Div., vol. 139, 1940, pp. 313-327.

20/ Crichton, Andrew B., How Much Coal Do We Really Have? The Need for An Up-to-Date Survey: Paper presented at the February 1948 A.I.M.E. Meeting, New York, N. Y.; A.I.M.E. Coal Technology, Tech. Pub. 2428, August 1948, 12 pp., Trans., Coal Div., vol. 177, 1948, pp. 26-38.

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The first part of the Bureau of Mines investigations will include all of the bituminous coals of the Eastern Province, as all of them coke to some degree. This will be followed by a similar survey of the Interior Province coals, and finally the fields of coking coal in the Rocky Mountain and Pacific Coast Provinces will be examined. The results of the study will be published on a county basis, giving the tonnages of each bed of coal in thickness groups of 14 to 28 inches, 28 to 42 inches, and over 42 inches. Also, the thickness of overburden, the ranges of quality, and the amounts mined out, if determinable, will be given for each bed. The reserves will be reported in three classes, namely, measured (proved), indicated (probable), and inferred (possible).

At the present time, the Bureau has five survey teams in the field - two in Pennsylvania, two in West Virginia, and one in Kentucky. On the basis of this work, coordinate studies will be made in the laboratory at Pittsburgh, Pa., on washability and coking properties of coals on which few commercial data are available, or coals of marginal character that might be considered for future use with proper preparation or blending.

The Bureau of Mines and the Geological Survey are working in close cooperation in these surveys, as both agencies are needed for a complete appraisal of the deposits, their quality, and their recovery.

Summary

In summarizing the subject of coal for coke production, it may be said that in comparison to other countries the United States is fortunate in having large coal resources many of which are suitable for the production of metallurgical coke. Twenty percent of the total reserves, on a heating-value basis, occur in the Eastern Province, and another 20 percent in the Interior Province. Most of the Eastern Province and especially the Appalachian region coals are strongly coking. The Interior Province coals are medium to weakly coking, and many of the deposits have a high ash and sulfur content. Only minor deposits of western coals are coking.

Ninety-five percent of the coal coked in 1947 came from the Eastern Province, in which the geologically inferred total coal reserves are estimated at 500 billion tons. Probably 25 percent of this, or 125 billion tons, may be considered as recoverable from beds 2 feet or more thick. The amount in thick beds, such as are being mined at present, is considerably less, and a further material deduction must be made for high-ash and high-sulfur coals that cannot be washed down to suitable percentages for metallurgical use. The actual available reserve under present mining and metallurgical practice is not known, but it is known that many of the best beds in Pennsylvania have been exhausted and that the steel industry is beginning to use notable amounts of lower-grade coking coals, which require the best possible cleaning to reduce the sulfur content to a reasonable amount.

The future calls for much research to develop more effective methods for removing ash-forming material and sulfur from low-grade coals not amenable to present methods of preparation. This will be required for utilizing the high-sulfur coals of southwestern Pennsylvania, northern West Virginia, and Ohio in the Appalachian region, and to a much greater extent in the Interior Province.

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Likewise, the depletion of the beds of strongly coking coal makes it necessary to increase the practice of blending high-rank with low-rank coking coals before the limited reserves of high-rank coals become exhausted. Fundamental research on the chemical and physical mechanism of the coking process also will aid greatly in finding means of making good coke from the larger reserves of poorly coking high-oxygen coals of the Interior Province.

The most disturbing factor in the coking coal-reserve situation is the limited supply of low-volatile bituminous coal essential for blending with most high-volatile coals for making a good metallurgical coke. Only 4 percent of the bituminous-coal reserves of the United States consists of low-volatile coal, increasing proportions (three times the amount used for coke production) of it are being used for fuel purposes because of its semismokeless properties. Its comparatively early exhaustion will require the development of a substitute, which probably can be done partly, at least, by the lower-temperature carbonization of high-volatile bituminous coal.

Fortunately, experiments along this line are in progress in this country and abroad. However, the cost of the artificial low-volatile coal will be greater than that of the natural material.

It is to be regretted that realistic figures on measured or even indicated reserves of coking coal are not available. However, a survey to obtain such data is now being conducted by the Bureau of Mines and the Geological Survey of the U. S. Department of the Interior. The first publication covering part of the low-volatile bituminous-coal area of central Pennsylvania probably will be issued in about 6 months, and in a few years we will know the answer to Andrew B. Crichton's question: "How much coal do we really have?"

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